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THE RELATION OF WINDFALLS TO BARKBEETLE EPIDEMICS

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OUTLINE

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Introduction

Because many species of tree-killing barkbeetles attack and develop their broods in recently-felled trees, it is easily assumed that certain types of forest debris become a potential threat to standing timber by serving as a breeding-ground for barkbeetle epidemics. Conditions such as those found in the slash left from large logging operations and the down trees due to violent windstorms, furnish certain barkbeetles with a favorable medium in which to multiply their numbers. When the supply of down material is exhausted, we may expect these insects to attack standing living trees in the vicinity to such an extent that a sharp increase in timber losses will follow.

The evidence of barkbeetle epidemics that develop in and around cutting operations and windfalls affords the only tangible proof of this theory. So far as observations are available, it is becoming apparent that the type of slash has much to do with the success with which barkbeetles increase their numbers and subsequently develop attacks in standing timber. In western yellow pine stands it has been found that only rarely do barkbeetles increase in logging and right-of-way slash to a point where they seriously menace the surrounding forest areas.[1] On the other hand, the recent study of two windfall situations in this type indicates that the loss of a considerable amount of standing timber has resulted from barkbeetle epidemics that had their origin in windthrown trees.

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[1]Division of Forest Insects, Bureau of Entomology, Cir. 411; [illegible] Relation of Insects to Slash Disposal.

WINDFALLS MORE FAVORABLE TO BARKBEETLES
THAN LOGGING AND OTHER FORMS OF SLASH

Slash is the term generally used to define the tops, limbs, cull logs etc. left in the woods after the trees have been cut. Above the stump the moisture supply for the inner bark is immediately cut off at the time of felling. Where the limbs have been lopped, evaporation of the inner bark moisture thru the foliage stops ~~respiration also is stopped~~. Abnormal moisture conditions are promptly set up within the cambium area in which barkbeetles feed, so that these insects must contend with either a rapid drying-out or a temporary excess of moisture in the inner bark, depending on the nature of the slash, site, and weather conditions. Although barkbeetles may enter the logs in slash material, conditions rapidly become unfavorable for brood development, and a high mortality often occurs during the period of larval feeding. Studies[2] by both Patterson and Person have shown that the mortality in slash is frequently so high that the number of new beetles emerging from a log is less than the number of their parents that attacked. Where this occurs, slash from an entomological standpoint becomes a benefit to the surrounding forest, as its net effect is to reduce the barkbeetle population in a forest area.

In windfalls, however, no such immediate disturbances of the trees' normal functions follow ~~immediately after felling~~. The majority of the trees are merely pushed over, leaving half the root system still in the ground. Moisture conditions in the inner bark therefore simulate those of the living tree for a much longer period than in logs where the tree is cut off at the stump. The roots are still able to supply moisture to the foliage, which in turn can continue the process

[2]Patterson, J.E. The Relation of Highway Slash to Infestations by the Western Pine Beetle; U.S.D.A. Tech.Bul.No.3.
[2]Person, H.L. Chilkoot Road Slash Study; Ms. Rept.

of respiration. The outstanding effects upon the tree are the loss of approximately half or more of its root system and a very radical disturbance of the light exposures of the foliage. Under these conditions a windthrown tree may continue to live in its prostrate state for several seasons, but its capacity to grow and to resist barkbeetle attacks becomes is greatly lessened. Its condition is comparable to that of a tree weakened both by drought and partial defoliation--conditions quite favorable for the attack of barkbeetles and the successful development of their broods.

Entomological Aspects Vary According to Type of Windfall

Windfall situations vary greatly in the volume of material that may occur during the course of a season within a given area. A few trees go down every season, not altogether as a result of unusual storms, but through failure of the root support, weakening of the bole by fire scars, decay and boring insects. This minimum type of damage, which seldom attracts notice in the heavier stands, differs in its entomological aspects from situations where from 20 to 50 per cent of the stand may be blown down in masses on the more exposed sites. It has been found that in areas where scattered windfalls occur little change, attributable to this source, follows in the barkbeetle infestation in standing timber; while around the mass type of windfalls barkbeetle epidemics of a virulent character may develop. Two situations where heavy windfall damage occurred in western yellow and Jeffrey pine have been studied in their entomological aspects, and give a fair index of what is to be expected in the types represented.

HISTORY OF TWO OUTSTANDING WINDFALL SITUATIONS IN PINE TYPE

1. The Upper Lake Windfall, California National Forest

a. Conditions Within the Area

A storm that occurred in ~~December 1920~~ January, 1921 caused the windthrow of an estimated volume of 25 million board feet of timber on an area of about 20,000 acres on the California National Forest. The wind coming from the northeast blew down trees in masses, in some places more than 50 per cent of the stand being thrown on slopes exposed to the worst violence. The volume of the more important species in down timber was estimated at:

Yellow pine	15	million board feet
Douglas fir	8	" "
Sugar pine	2	" "

Within this region the important tree-killing beetles of these hosts are:

Yellow pine - Western pine beetle (Dendroctonus brevicomis Lec.)
Engraver beetle (Ips confusus (Lec.))
(Ips oregoni (Eich.))

Sugar pine - Mountain pine beetle (Dendroctonus monticolae Hopk.)
Engraver beetle (Ips confusus (Lec.))

Douglas fir - ~~Douglas fir beetle~~ Flatheaded borer (Dendroctonus pseudotsugae Hopk.)
(Melanophila drummondi (Kirby))
Fir engravers Pseudohylesinus Nebulosis Lec.
Scolytus subscabrosus Lec.

Preceding the windstorm, the main losses due to insects in this region were caused by the western pine beetle in yellow pine and the mountain pine beetle in sugar pine. For a long period this infestation has remained in an endemic condition, averaging not over 25 trees killed annually per timbered section. Very little insect loss has been found in living Douglas fir in this area. The two species listed above, together with a number of secondary engraver beetles and borers, are common in recently-felled logs.

b. Developments Following Windfall

With the sudden creation of this great volume of down logs it was obviously impossible for this limited barkbeetle infestation to attack and infest all the favorable host material in the spring of 1921. It was necessary first that the beetles increase their numbers. This increase developed rapidly during the first season after the windfall, but occurred almost entirely in the down logs. The amount of infestation in the standing trees that were killed did not increase materially over that of the two preceding seasons. In the spring of 1922 there was no indication from the number of standing infested trees that a potential barkbeetle outbreak existed in the region of the windfalls.

Suddenly, during June and July 1922, the western pine beetle began to attack standing trees in unprecedented numbers. Trees were killed in groups of 50 to 100, whereas in previous seasons such killing occurred only in single trees or in groups rarely exceeding four or five. The mountain pine beetle in sugar pine developed a similar increase, [illegible] of this host in the stand. Totaling both species, the loss caused by one seasonal generation of the beetles suddenly increased from 25 to more than 200 trees per timbered section.

In the fall of 1922 the attacks of the overwintering generations of the beetles showed a very pronounced falling-off in numbers. The large grouping of the attacks disappeared, and the loss dropped to less than 30 trees per timbered section. During 1923 this type of loss dropped to a point even lower than that for 1921, the year preceding the windfall. The progress of this outbreak in combined yellow pine and sugar pine losses is shown in the following table, based on a hundred per cent cruise of a check area of 786 acres:

Year	No. Standing Trees Killed	Board Foot Volume
1921	28	60,190
1922	228	403,810
1923	15	25,990
1924	25	12,970

Estimates of both windfall and insect losses for the [illegible] area and the surrounding territory are shown in Diagram I.

c. Distribution and Character of Insect Outbreak in Standing Trees

This distinct outbreak of 1922 was localized mainly in the region of the windfall. [illegible] the yellow pine belt of northern California [illegible], which supports the assumption that the sudden outbreak in 1922 in and around the windfall areas was due to beetles coming out of the down logs. The attack of these beetles on standing trees was not altogether localized, however, in the immediate vicinity of the windfalls themselves. Although the heaviest killings were found close to the largest bodies of windthrown trees, distant groups of beetle-killed trees were found at points six to eight miles distant from any mass windfalls.

The striking absence of any noticeable killing of Douglas fir is one of the outstanding features of this situation. This host tree suffers very little from barkbeetle losses in the Pacific Coast region, and neither before nor after the windfall did any serious loss develop. Apparently the infestation in this host was of such a secondary character that it could not gain momentum in standing timber after the down logs became unsuitable for brood development.

Another outstanding feature was the absence of engraver beetle outbreaks in yellow or sugar pine. The species of Ips are common in down logs and at times cause small local outbreaks in living trees on the poorer sites during drought periods. In this case, although engraver beetles were noted in some of the down logs, they did not appear as a factor in the subsequent killing of standing timber.

d. Probable Cause of Epidemic and Its Decline

~~PROBABLE CAUSE OF EPIDEMIC AND ITS DECLINE~~

In October 1924 Mr. H.L. Person of the Bureau of Entomology and Supervisor Coffman of the California National Forest carried out a brief survey to determine the final developments connected with this outbreak. One object of this study, which supplemented previous surveys in 1922 and 1923, was to secure enough data to indicate the source of the beetles caus ing the 1922 outbreak and the cause of the remarkable decline in their numbers that occurred in the fall of that year. Strip surveys were run through parts of the windfall area and logs examined to determine the effective emergence per square foot in this class of material; in addition, standing beetle-killed trees were selected and sample bark areas counted to determine the same ratio of attacking beetles to their effective progeny.

Owing to the limited time available, and the fact that much of the bark material had in two years deteriorated to the point where accurate counts were impracticable, it was not possible to carry this line of analysis far enough to secure conclusive evidence. The results secured indicated, however, that a high percentage of the pine windfalls were attacked only lightly by beetles, and that in this material the average emergence per square foot was much lighter than in standing beetle-killed trees. Estimates based on the averages secured indicated that not enough beetles had developed in the windfalls to account for the number of attacks in standing trees in the summer of 1922. This would indicate that some attraction in the vicinity of the windfalls may have lured these insects from outside areas to augment the sudden killing of standing trees during the summer of 1922. It was adequately established, however, that only a small percentage of the beetles making the 1922 attacks could have come from standing infested trees on or near the area involved in the epidemic. The beetles that left the windfalls must have been the largest contributing source of supply for the attacks that occurred during the summer of 1922.

The cause of the epidemic's sudden decline was also found to be complicated, but at least one obvious factor dominated all other considerations—the overcrowding of the parent beetles in attacking the large groups of trees that were killed during the summer of 1922. This is brought out by a comparison of the number of beetles attacking and their subsequent progeny emerging per square foot in trees of the 1921, 1922 and 1923 generations.

Season	No.Beetles per square foot of Bark Surface	
	Attacking	Emerging
1921	27	80
1922	41.2	48.5
1923	29.2	86.5

This indicates an overconcentration of attacks in trees of the 1922 generations. The large groups of trees killed during that season were the result apparently of a tremendous building up of the barkbeetle population within a local area. The attacks within the bark surface were concentrated to such an extent that there was not

enough food to supply all the developing broods; as a result the emergence was only half the normal for the preceding and subsequent seasons. Parasites and predators were also considered, but only to a small extent can they account for this diminution of effective progeny in the broods.

2. The Inyo-Mono Windfall of 1925

A. Conditions Within the Area

A storm that occurred in February 1925 caused the loss of a volume of timber estimated as 12½ million board feet on an area of 32,000 acres east and north of Mammoth, Calif. The conditions involved in this blowdown differed greatly as to site and type conditions from the one just described. About half this loss occurred on a few small local areas, totaling 2640 acres. From 20 to 80 per cent of the stand was blown down where the heaviest losses occurred, but this condition merged into areas where the windfall loss was less than 2 per cent of the merchantable standing timber.

The principal host tree involved was Jeffrey pine. White fir and lodgepole pine composed so small a proportion of the stand as to be negligible from an entomological standpoint. The important barkbeetle enemies of Jeffrey pine in the area are Dendroctonus jeffreyi and Ips oregoni. The former attacks primarily the mature trees, and for several seasons preceding the windfall had been in an endemic status, averaging 20 trees or less killed annually per section. The latter develops mainly in tops and young trees, appearing occasionally in sporadic local outbreaks.

b. Developments Following Windfall

Barkbeetles, mainly Ips oregoni, began to attack the down material during 1925, but only a small percentage of the logs became infested during the course of the season. This attack, with successful development of the broods, continued during the 1924 season. Dendroctonus jeffreyi attacked the lower side of occasional logs during the seasons of 1923, 1924 and 1925, but did not become noticeably abundant until 1926.

c. Distribution and Character of Infestation in Standing Trees

No damage beyond that due to endemic infestations appeared on or around the windfalls until the autumn of 1924. In August and September of that year thousands of trees above pole size were top-killed by Ips oregoni, and large groups of small trees were entirely killed by the same barkbeetle. This damage occurred on or near the areas of heaviest windfall. This outbreak was limited entirely to the fall attacks of the 1924 season, and aside from the top-killing injury did not result in serious losses of mature trees.

No Ips attacks of importance occurred anywhere on the area in 1925.

During the summer of 1925 the Jeffrey pine beetle attacked the lower trunks of many standing trees previously top-killed by Ips oregoni. The combined losses of Ips oregoni and D. jeffreyi were estimated at 6 million board feet for the 1924 and 1925 seasons.

During 1926 the Jeffrey pine beetle attacks in standing mature trees were heavier than for any preceding season. This loss averaged more than 100 trees per timbered section, and was widely distributed throughout the stand instead of being localized around the areas of heavy windfall,

In 1927 it was found that this epidemic condition of the Jeffrey pine beetle was subsiding; and although the total loss figures for that year are not complete, they will be less than for either 1924 or 1925. The course of these infestations from 1922 to 1927 is shown in Diagram II.

d. Probable Cause of Epidemic and Its Decline

In this situation, as in the California area, insects coming from the favorable breeding-ground of windfall trees were the largest contributing factor to the outbreak in standing timber. There was, however, a radical difference in both the character and timing of the outbreak. A short-lived Ips outbreak occurred the second season after the blowdown, just about as the western pine beetle epidemic developed in the yellow pine type on the California area. However, the Ips epidemic was followed by a more gradual and sustained increase of the Jeffrey pine beetle, which reached its peak the fourth season after the blowdown. Its decline was equally as sudden as that of the Ips and western pine beetle outbreaks.

The causes of the decline of the Ips outbreak were apparently due to the failure of these insects to maintain their numbers after attacking the standing trees. That the D. jeffreyi outbreak also subsided from the same cause is shown by an unusual number of trees on the area that had successfully "pitched out" or resisted attack. Still another factor in the subsidence in numbers of D. jeffreyi was the increase of certain species of roundheaded borers which closely followed the barkbeetle attacks. The roundhead larvae developed rapidly enough to deprive the barkbeetle broods of their normal food supply in the inner bark, resulting in a high mortality.

In both the situations described there is little evidence that barkbeetle epidemics had caused losses of similar severity in the past. The stands surrounding these windfalls are apparently not susceptible to severe losses because of certain factors connected with composition, age and site. Had the windfalls and the subsequent insect outbreaks occurred in pure stands of overmature yellow pine, it is possible that the epidemic situation would have been sustained for a much longer period.

POSSIBILITIES OF CONTROL OR SALVAGE TO PREVENT INSECT EPIDEMICS

The loss resulting from unusual and violent windstorms in virgin timber stands cannot be prevented and must always be accepted as a hazard to the owner. Not only the loss of the windthrown trees, but the setting up of conditions that greatly increase the fire hazard and the possibility of insect losses, must enter into the liabilities. The matter of salvage or control measures, with the object of reducing both the fire hazard and insect menace, can therefore be considered with profit.

In any serious windfall situations that may develop the owner has three possible lines of action to consider in the protection of the values at stake. They are:

1. Let conditions stand, accepting whatever subsequent losses may develop, and depending upon nature to work out finally an adjustment of the disturbance;

2. Apply artificial control measures, with the object of preventing insect losses in standing timber; and

3. Utilize the windthrown logs in order to secure whatever salvage is available from this material and at the same time remove a fire and insect menace.

The first course is probably the best one to follow where timber values are so low that the cost of control or salvage work would exceed the value of the probable amount of timber that would be saved. In fir stands, where there seems to be little probability of subsequent insect outbreaks, control work would be of no advantage.

The application of barkbeetle control measures would offer some advantages in pine stands where fairly heavy losses are likely to develop from the windfalls. This course would be worth considering only in susceptible stands where high stumpage values are at stake. The accepted methods of barkbeetle control require the cleaning up and

burning of a considerable amount of the slash material, which improves the fire-hazard conditions within the area. From this standpoint control work affords an added advantage.

In the two situations that have been studied, control work in non-susceptible stands would appear to be useless after the beetles leave the down logs and enter the standing trees, as natural factors were capable of bringing about a decline as effective as can be secured from artificial measures, within one season after the beetles become epidemic in standing trees.

Obviously the point of attack where control would be most useful is upon the barkbeetle infestations while they are still breeding in the windthrown trees. However, the conditions that ordinarily exist in recent windfalls offer numerous disadvantages to the application of control measures. Cruising out of the infested down logs would require intensive strip methods, as they are not visible from a distance like standing infested trees. The distribution of the broods within the logs is irregular, and a large percentage develop only occasional patches of infested bark. Compared with the infestation in standing trees, a much larger volume of timber must be treated to kill the same number of beetles.

Salvage operations seem to offer the greatest advantages where values are high and there is an available means of utilizing the down material. If the logs are removed from the area before the barkbeetle broods can emerge, no special control methods are necessary. However, if they are left in the area after the time of emergence, the logs should be treated by the accepted methods of peeling, peeling and burning, or sunscuring the infested bark.

In the case of either control work or salvage operations, a clean-up should be completed within two seasons after the occurrence of the windfall, in order to head off possible outbreaks in standing trees.

Prompt salvage of the down material appears to be the most feasible of all remedies to prevent the fire and insect hazards connected with windfall situations. Even though the salvage operations cost more than the utilization value of the material, this course may in the long run prove profitable by preventing losses of equal value ~~due to~~ resulting from uncontrolled insect outbreaks in the surrounding stands.

SUMMARY

1. Windthrown trees, due to the fact that part of the root system remains in the soil, retain moisture conditions in the inner bark that are favorable to barkbeetle attack and brood development. These conditions persist much longer in windfalls than in forms of slash where the tree is cut off at the stump.
2. Pine windfalls are especially attractive to barkbeetles. Where large masses of windfalls occur in this type, conditions are favorable for decided increases of the barkbeetle population, due to the building-up of several generations in the down logs. These beetles may subsequently attack standing green trees on and around the windfall area.
3. Two outstanding windfall situations in California have been studied in their entomological aspects: (a)

In the Upper Lake area, a severe outbreak of Dendroctonus brevicomis occurred in standing yellow pine during the second season following the windfall; a similar outbreak of Dendroctonus monticolae also occurred in sugar pine. In Douglas fir, which composed about 32 per cent of the windthrown material, neither barkbeetles nor other insects breeding in the down logs attacked standing trees within the area to a noticeable extent.

On the Inyo-Mono area, where the type was largely Jeffrey pine, an outbreak of Ips oregoni, killing tops of larger trees and smaller trees in groups, occurred during the second season following the windfall. Dendroctonus jeffreyi increased its attacks during the second and third seasons after the windfall, and during the fourth season became epidemic in standing trees.

4. In both situations studied, the barkbeetle losses suddenly declined to an endemic status immediately after reaching the peak of the epidemic in standing timber. The losses of standing timber during the epidemic period just about equaled the loss due to windthrown trees.

4 5. The sudden decline of epidemic conditions so n after the beetles went into the standing timber is due to a complex of causes. In the main it is evident that barkbeetle epidemics build up by special conditions like windfalls cannot maintain their momentum after the beetles attack stands that are not naturally susceptible to these infestations.

5 6. The insect menace arising from heavy windfall situations in the pine type may be reduced either by barkbeetle control measures or by prompt salvage of the windthrown logs. Control work would be most useful if applied before the epidemic develops in the standing trees. Due to certain disadvantages involved in treating barkbeetle infestations in down logs, control would be profitable only in susceptible stands of high value. Salvaged material should be moved out of the area or else treated by accepted control methods before the beetles can emerge from the down logs.

6 7. Either control or salvage operations should be completed within two seasons after the windfall occurs, in order to prevent the possibility of insect outbreaks in standing timber.